DOCUMENT RESUME

ED 291 160 EA 019 917

AUTHOR Vickery, E. C.
TITLE Potential Uses of Computers for Planning and Designing Educational Buildings. Educational Buildings Occasional Paper No. 3.
INSTITUTION United Nations Educational, Scientific, and Cultural Organization, Bangkok (Thailand). Regional Office for Education in Asia and the Pacific.
PUB DATE 85
NOTE 61p.
PUB TYPE Guides - Non-Classroom Use (055) -- Reports - Evaluative/Feasibility (142)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Architectural Programing; *Building Design; *Computers; Computer Software; *Educational Facilities Design; Elementary Secondary Education; Foreign Countries; Information Technology; *School Buildings; Technological Advancement
IDENTIFIERS Thailand (Bangkok); UNESCO

ABSTRACT

This publication is an introductory guide to the use of computers for the planning and design of educational facilities. After a brief introduction, the first chapter provides a flowchart of the planning and design process for educational buildings. Chapter 2 explains elementary computing concepts such as hardware and software and diagrams the processes of computing. Chapters 3, 4, 5, and 6 describe potential computer applications, respectively, to the macro planning stage, the research and development stage, the micro planning stage, and the implementation stage of educational building design. Chapter 7 delineates considerations for implementation of computer applications, including user requirements, software and hardware selection, and personnel. Chapter 8 provides 12 summary sheets for implementing computer applications at each stage of educational building planning and design. The document concludes with an overview of the prospects for computer use in this field. (TE)

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Educational Buildings:
Occasional Paper No. 3

Potential Uses of Computers for Planning and Designing Educational Buildings

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Unesco. Regional Office for Education in Asia and the Pacific.

Potential uses of computers for planning and designing educational buildings. Bangkok, 1985.

52 p. (Educational buildings. Occasional paper no. 3)

1. EDUCATIONAL BUILDINGS – PLANNING SYSTEMS. 2. EDUCATIONAL BUILDINGS – COMPUTER-ASSISTED DESIGN. 3. BUILDING DESIGN – COST/BENEFIT ANALYSIS. 4. COMPUTER-ASSISTED DESIGN – EDUCATIONAL BUILDINGS. I. Title. II. Series.

727

Educational Buildings
Occasional Paper No.3

Potential Uses of Computers for Planning and Designing Educational Buildings

by DR E.C. VICKERY
UNESCO. DECEMBER 1984

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Published by the
Unesco Regional Office for Education in Asia and the Pacific
P.O. Box 1425, General Post Office
Bangkok 10500, Thailand

Printed in Thailand

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BKEB/85/OP/90-2500

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INTRODUCTION

Unesco, Bangkok endeavours to develop its programme activities around the current interests of the 31 Unesco Member States in Asia and the Pacific. In reply to a request for suggested activities in the educational facilities programme, two Member States requested training on the use of computers for programming and design of educational buildings. It was with some embarrassment that Unesco replied it was technically unable to respond to this request because of our unfamiliarity with the field! To fill that gap in our institutional knowledge a study was commissioned.

The rapidly growing use of computers for architectural and engineering purposes has largely taken place in the private sector while the school building units with which Unesco maintains close contacts continue to prepare drawings and to calculate costs using traditional techniques. This publication which is the product of the above mentioned study should help these units to consider ways in which they might modernise their working procedures through giving a broad view of how computers might be used for the planning and design of educational facilities. It has been conceived as the "primer" in this field and, thus is written so as to be understood by readers who have no background in computers.

The term "computing" has come to cover a vast range of machines and computer programmes which also have vastly different capacities and correspondingly different costs. This publication will help to identify which kinds of machines and programmes are liable to be the most cost effective for a wide variety of educational facilities applications. These vary from preparing national inventories of existing facilities to estimating building material requirements for a single building. Consequently it will be useful to educational planners as well as to architects and engineers.

Should the reader find the type face in this publication a bit unusual, it is because it has been reproduced from a computer print out. The author, Dr. E.C. Vickery has used a micro computer for preparing the drafts and final manuscript. The cover makes use of a small portable computer used in Unesco, Bangkok.

Dr. Vickery is uniquely qualified to prepare the study. He is employed by a major architectural firm in Singapore which is involved in construction projects in several countries in Asia. He holds a doctors degree from Bristol University where he studied computer applications to architecture and carried out research on measurement of the flexibility of buildings for which he made extensive use of a computer. His experience with educational building research and design began even before his formal architectural training when he worked as a volunteer draftsman and model maker at the Asian Regional Institute for School Building Research in Colombo.

1.0 THE EDUCATIONAL BUILDINGS PLANNING PROCESS

The objectives and problems of the planning and design of educational buildings in Asia and the Pacific have been well described elsewhere and it is not intended to reproduce these considerations here. However, a useful framework for the discussion is the model of the educational buildings process described by El Jack and Almeida (1). This model is depicted in figure 1. The discussion in this paper is related to this model.

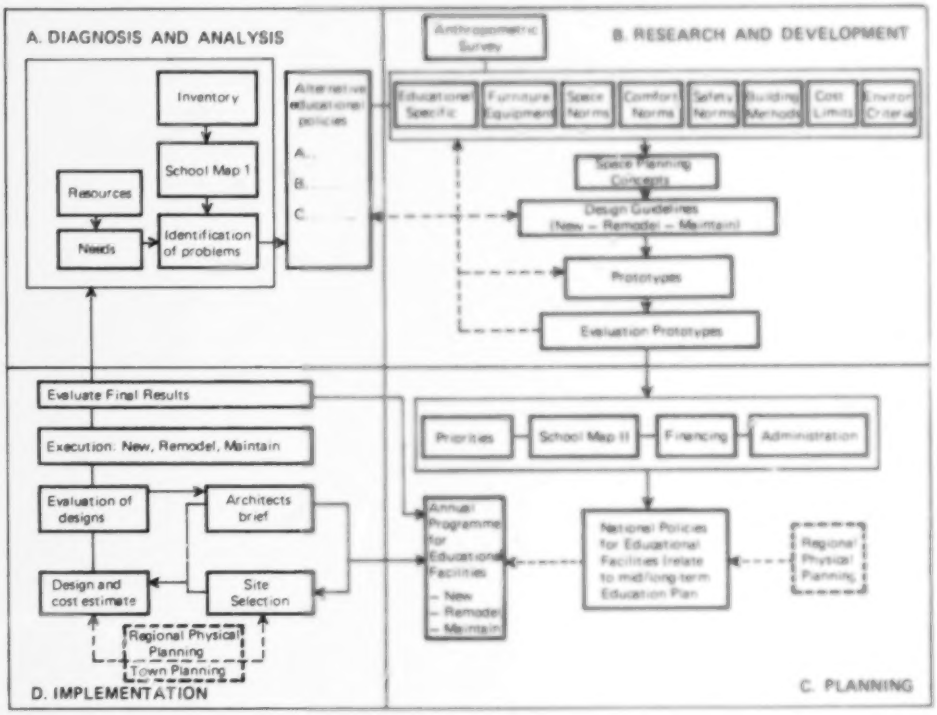


Fig. 1. The Educational Buildings Planning and Design Process

1. Kamal El Jack & Rodolfo Almeida. Planning Educational Buildings: Basic Concepts. Paris, Unesco, 1980.

The essential feature of the process is that it consists of four stages, as follows:

a) **Diagnosis and analysis:** in which educational policies are identified and the resources available for their implementation are assessed. Hence alternative strategies for implementation are devised. As envisaged in the model, this stage of the process takes place at the more global levels of decision-making and may thus be known as the macro planning stage.

b) **Research and development:** in which the objective is to ensure that the implementation of any strategy produced in the first stage is to adequate standards. To this end, research and development are required to establish appropriate norms and criteria. The research and development stage also includes the construction of prototypes which may be evaluated with reference to these norms and criteria.

c) **Planning:** in which those responsible for the physical provision of educational buildings assess the specific problems associated with, and the resources available for, the construction of educational buildings in particular localities according to the dictates of the strategies produced in the macro planning stage. The outcome of this stage of the process is decisions regarding the exact locations, types and sizes of educational buildings. Hence, it may otherwise be known as the micro planning stage.

d) **Implementation:** in which the decisions reached in the micro planning stage are implemented.

2.0 ELEMENTARY COMPUTING CONCEPTS

As a background to the discussion, it is necessary to introduce some basic computing ideas and terms. The reader who is already familiar with such matters is advised to proceed to Section 3.0.

In essence, a computer is an electronic machine capable of storing data in its memory and of performing operations on those data according to a set of instructions known as a program. Peripheral to the computer may be a number of devices such as storage disks and tapes, which increase the amount of data and programs to which the computer can gain access, and display screens, printers and type-writer terminals which may be used to input and output data and programs.

The computer and its peripherals are collectively referred to as hardware, computer programs being known as software, a distinction which provides a useful basis for a description of those aspects of computers and computing which will be of most relevance to this discussion.

2.1 Computer hardware

Currently, it is possible to distinguish between three types of computer, as follows:

a) **Mainframe computer:** the largest type of computer and, until 15 years or so ago, the only type of computer available. In terms of size, a mainframe computer is not unlike a number of domestic refrigerators. Its size apart, the mainframe computer is characterized by its high speed, high computing power and high cost. It is generally able to support a large number of users simultaneously.

b) **Minicomputer:** medium-sized and of moderate cost. Typically, minicomputers are about the size of one or two office filing cabinets. Generally, minicomputers can support a small number of simultaneous users.

c) **Microcomputer:** a small computer, about the size of an electric typewriter. Microcomputers are based on the microprocessor, a processing unit constructed on a single integrated circuit and which accounts for the microcomputer's small size and low cost. It is the microcomputer, in the form of the so-called 'personal computer', which has led to the popularization of computing.

Developments in computer technology are tending to blur the distinctions between the different types of computer so that, whereas physical size was once a realistic descriptor of computing power, this is no longer so. Rather, computers may more appropriately be described in terms of their speed of operation, the volume of work they are able to carry out and the number of users they can support at any one time.

The two most important parts of the computer are the central processing unit and the memory. The central processing unit, which is the heart of the computer, handles the data and executes the instructions contained in computer programs. Computer memory is used for the storage of general instructions to the computer on how to perform certain operations such as addition and subtraction, and of computer programs and the data necessary for the execution of those programs.

The computer is served by other hardware components known as peripherals. The range of peripherals available is large. Descriptions of the most common of the peripherals are given below.

a) **Disk and tape storage devices:** Computer memory is limited in size and it is usual to store programs and data on external storage media such as disks, which are magnetically sensitized and appear rather like gramaphone records, and tapes similar to acoustic recording tapes. The peripheral which houses a disk is known as a disk drive whilst that which houses a tape is known as a tape recording device.

b) **Typewriter terminals:** This device, which is like a typewriter, enables the computer user to communicate with the computer. For example, the user may use the terminal to instruct the computer which particular program to run. Terminals may also be used to load programs into the main memory.

c) **Visual display unit:** This is a device not unlike a television screen to which the computer may output the results of its processing and which also enables the user to monitor the status of the computer operations.

d) **Printers and plotters:** These are devices which enable the computer's output to be printed. Printers are usually used for the output of alphanumeric data whilst plotters enable graphic data such as drawings to be printed.

2.2 Computer software

Computer software is the generic term for computer programs, the sets of instructions which tell the computer how to perform particular tasks. Instructions to the computer are couched in the form of a code known as machine code. To all but the most dedicated and knowledgeable of programmers, however, programming in terms of machine code is both difficult and cumbersome. It is usual, therefore, to write computer programs in one of the so-called 'high-level languages' such as BASIC or FORTRAN. These are computer languages which bear some relation to English and which are therefore easier to use. A program written in such a language will be translated into the necessary machine code by a special computer program known as a compiler.

A number of programs are commercially available for the performance of specific tasks such as, for example, payroll accounting. Where there is no appropriate software available, it will be necessary to write, or to commission the writing of, the required programs.

2.3 The process of computing

With these essentials in mind, it is now possible to consider how the various pieces fit together to form the process of computing. Typically, the procedure in any form of computing may be viewed as consisting of the three consecutive stages of input, process and output, related as shown in figure 2.

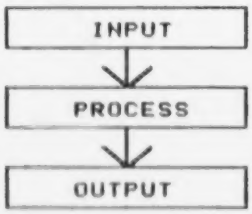


Fig. 2. The process of computing

To each of these stages corresponds both one or more hardware and software components, as shown in figure 3.

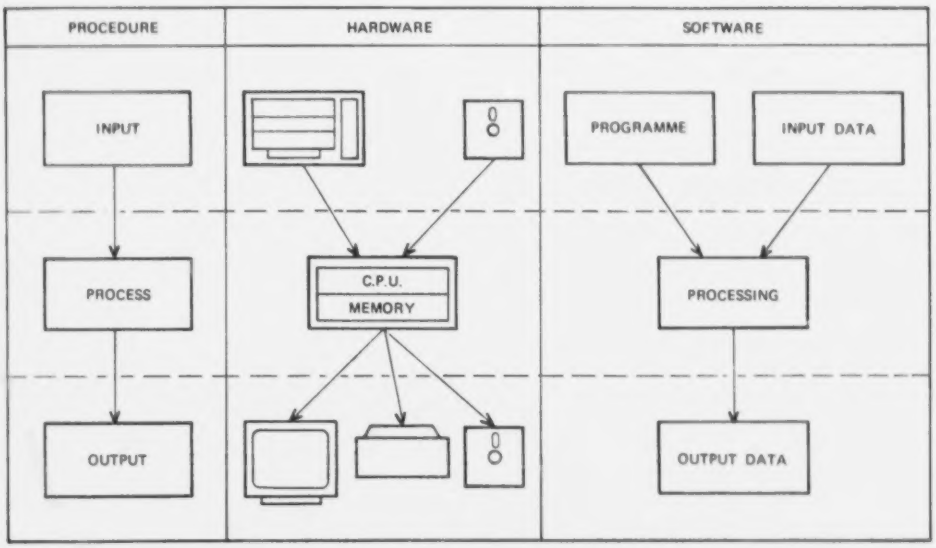


Fig. 3. The process of computing : Hardware and software components.

3.0 POTENTIAL COMPUTER APPLICATIONS TO THE MACRO PLANNING STAGE

In relation to its potential for computer applications, the macro planning stage has two important characteristics. These are:

a) It involves data collection and organization. These are manifest in the processes of preparing and updating inventories of educational facilities and of preparing school maps.

b) It involves data analysis. This is manifest in the process of identifying problem areas, that is, in the process of comparing existing levels of provision with anticipated levels of demand.

The activities of data collection, organization and analysis are collectively known as data processing. Data processing is concerned with the storage and manipulation of data, the purpose of the latter being to extract information from the data. Where these operations are performed by computer, the process is known as electronic data processing. This definition is a potential source of confusion since it may be argued that, ultimately, all computer applications are forms of electronic data processing. However, throughout this text, the more limited meaning of electronic data processing, as described above, will be applied.

It is clear, therefore, that the compilation of inventories, the preparation of the school map and the subsequent analysis of the data collected are all strong candidate activities for computer applications. In order to understand how electronic data processing may be of benefit in the macro planning process, it is first useful to understand some of the principles involved. These may be indicated with reference to the following:

a) **The structure of data.** An important concept in data processing is that data are structured. Data do not exist in isolation as in this form they would have no meaning. Rather, their meaning is given by their relationships to other data. For example, the fact that a school exists in a certain location would have little value in a facilities inventory unless details regarding its size, student population and staff strength were also known. The structure of data, or data structure as it is more commonly known, will vary according to the context in which the data are required.

b) **Database.** A set of structured data is known as a database. This is not necessarily a computing term. For example, a dictionary is a database in which the data are related in alphabetic order. A database may, however, be stored on a computer.

c) **Database processing system.** In computing terms, this refers to the software which controls the storage and retrieval of data into and from a database stored on a computer. Thus, a database processing system ensures that the data are stored in the database according to the correct structure and controls the retrieval of data in that, given its knowledge of the data structure in question, it carries out a search of the database for the data required. Retrievals may be simple, as for example in the case where the user might request the database processing system to list all the primary schools stored in the database. On a more complex level, the user may, for example, request data concerning all primary schools having less than 6 classrooms and more than 250 pupils.

d) **Applications programs.** An applications program is a computer program designed to perform a specific task, the execution of which requires the input of data retrieved from the database. For example, an applications program might be designed to examine the relationship between school enrolment and population density. Such a program would take as its input data describing the catchment area and the student population.

e) **Database system.** This refers collectively to the database, the database processing system and one or more application programs, all related as shown in figure 4.

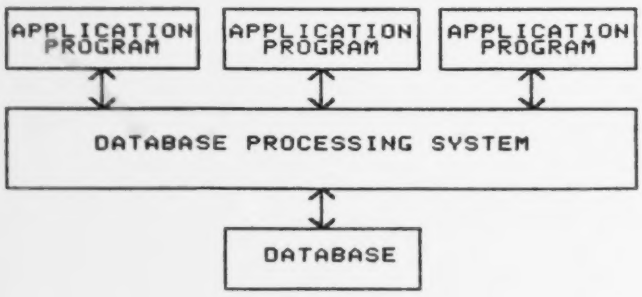


Fig. 4. **Database system.**

In the application of electronic data processing methods to the macro planning stage, the activities of data organization and storage would be the subjects of a database and a database processing system. The activity of quantitative analysis would be the subject of the relevant applications programs.

It should be noted that much of database technology is still new and the terminology is thus not yet standardized. Whilst the definitions given above should generally be acceptable, readers who pursue this topic further may expect to encounter alternative terms and definitions. It may also be noted that the relationships indicated in figure 4 refer to a particular approach to data processing, selected because it illustrates as complete a range of the principles as possible. Although, in practical terms, this approach differs considerably from many others, these differences are not significant in terms of the discussion here.

The interesting aspect of the application of computers to the data processing activities of the macro planning stage is not merely that the potential exists, but that such application may considerably enhance the performance of those activities, as follows:

a) The physical problem of the storage of data would be eased. For example, the contents of thousands of inventory forms could be accommodated on a few disks.

b) It would be possible to process the data with greater ease and, therefore, speed. With manual data processing methods, it is necesary for those carrying out the processing physically to inspect the data, particularly upon retrieval prior to performing some analysis. In the case of electronic data processing, the processing personnel remain remote from the data and have only to specify, by means of an application program, the output required. Thereafter, the retrieval of the data and its subsequent analysis are performed automatically.

c) For similar reasons, the updating of inventories would become simpler and faster. For example, the user would not need to inspect the whole database in order to determine where to insert new data as this would be a function of the database processing system, the user having only to specify the action required.

d) The data stored could be made easily available to a large number of people. This is so for two reasons. First, the method of storage, as for example on a disk or a tape, facilitates easy duplication and transportation of the data. Second, there exists the possibility of linking computers over great distances by means of the telephone system. In this case, there would be no need to transport the data in a physical form since direct access to it could easily be gained irrespective of distance.

As described above, electronic data processing methods offer the potential of increasing the ease and speed of performing data processing tasks. These benefits have an important consequence. The value of data lies in the information that may be extracted from it. The extraction of information is achieved by analysis of the data. The more ways in which it is analyzed, the greater the information extracted. However, the long and tedious nature of retrieving and analyzing data using manual methods may act as a deterrent to such comprehensive analysis. Where analysis becomes easier and quicker to perform, as in the case of electronic data processing, then this deterrent does not exist. Rather, the capacity to perform analyses is constrained only by the availability of applications programs.

A final consideration also concerns the capacity available for data processing. The amount of data handled in connection with school building programmes is very large and, in the future, will undoubtedly become larger. The danger is that the capacity to process the data may not increase in proportion to the growth in the amount of data. Electronic data processing provides a means for coming to terms with this problem since, for many types of database system, the size of the database does not significantly affect the speed of processing. It should be emphasized that this is not true of all database systems so that where the database is expected to be large, it is essential to select the appropriate type of system. Given proper selection, however, the benefits are clear.

4.0 POTENTIAL COMPUTER APPLICATIONS TO THE RESEARCH AND DEVELOPMENT STAGE

The aim of the research and development stage is to identify ways and means of enabling qualitative improvements in educational buildings with respect to a given set of educational and physical constraints. As may be seen from figure 1 the fulfilment of this aim involves the following activities:

a) Determination of the educational specification.
b) Establishment of norms and criteria.
c) Development of building methods.
d) Determination of cost limits.
e) Preparation of design guidelines.
f) Design of prototypes.
g) Evaluation of prototype designs.
h) Construction of prototypes.
i) Evaluation of constructed prototypes.

Activity a) is essentially carried out in the two planning stages and will not be discussed here. Activities c),f), h) and i) are unlikely to be suitable subjects for computerization. There is potential for computer applications to the other activities. Descriptions of these applications follow.

4.1 Establishment of norms and criteria

Although possible, the application of computers in the establishment of norms and criteria is generally of a limited and piecemeal nature. For example, computers may be used to apply statistical methods of analysis to anthropometric, thermal and illumination data with a view to establishing comfort norms.

4.2 Determination of cost limits

A fundamental problem in the design of educational buildings in the region is the provision of appropriate physical facilities at the minimum cost. The costs of such facilities are dependant on a number of factors such as the curriculum, the utilization of spaces, the range of sizes of teaching groups, the level of provision of ancilliary spaces, building methods and so on

The problem described above exhibits the characteristics of a class of problem known in operations research or systems analysis terms as optimization. The essentials of the optimization process are the satisfaction of a number of criteria, known as constraints, with respect to some optimum objective, in this case, that of minimizing the cost.

The discipline of operations research offers a variety of techniques for the solution of such problems, the choice of technique depending on the exact nature of the problem. These techniques may broadly be classified as methods of mathematical programming. The use of the term programming in this context should not be confused with programming in the computer software sense. In the mathematical programming context, programming refers rather to a planning process than to a set of computer instructions.

The construction of a cost limit model in which the solution is derived by mathematical programming techniques is a possibility worth investigating for, if successful, the model would represent not only a useful research tool but also a valuable decision-making model in the planning and design of educational facilities. Such speculation lies, however, beyond the scope of this discussion.

Many, but not all, mathematical programming techniques rely for their satisfactory application on the use of computers. This is due in part to the multi-factorial nature of the problems encountered and in part to the fact that the large amount of numerical manipulations involved in their solution cannot realistically be performed without a computer. In this sense, therefore, the implementation of a cost limit model of the type described above must be regarded as a potential computer application.

4.3 Preparation of design guidelines

An important part of the research and development stage is the conducting of research into various aspects of space planning. As a result of this research, design guidelines concerning the nature of the spaces required in an educational building and of the relationships between them are developed.

These activities offer some scope for computerization, particularly in the case of research into the relationships between spaces. For example, the provision of corridors in a school building is, in the strictest sense, wasteful since

corridors contribute nothing towards the learning process. Rather, they merely facilitate movement between spaces in which learning takes place. On this basis, an objective in school building design would clearly be to reduce the amount of corridor space provided.

Nonetheless, in reducing the amount of corridor space, the general criterion of providing sufficient space in which to facilitate efficient movement must still be acknowledged. Traditionally, this criterion has been satisfied by the application of rule-of-thumb methods. By their very nature, such methods are only capable of producing approximate results. However, were it possible to make more precise predictions of the amount of space required it may be possible to effect considerable savings in building costs.

The basic characteristic of this type of problem is that it is concerned with the cumulative effect of a number of people acting independently. The number of interactions between a group of people, each acting independently within a given space, is potentially very large and it is for this reason that rule-of-thumb methods are inadequate.

However, the computer, with its capacity for processing large numbers of variables within a short space of time, provides an effective means for modelling the movement of people within buildings. The modelling technique used in this case is that of simulation which may be applied manually in the case of small scale problems but which is almost wholly dependent on the availability of computers for large scale applications.

Simulation modelling may also be used to simulate certain random events such as the formation of queues. A good example of this, in the school building context, would be the use a queuing simulation model to determine the adequacy of the level of toilet provision. For example, it may be assumed that the toilet facilities in a school will be in greatest demand during a break period. It would be possible, for a given student population and a given duration of break period, to determine, by application of an appropriate queuing simulation model, the minimum number of toilets required to service the student population within the allotted break period.

4.4 Evaluation of prototype designs

The value of constructing prototypes is that it helps to highlight some of the less predictable consequences of design decisions. A large number of the consequences of design decisions are, however, readily predictable. The prediction of the thermal performance of buildings is a case in point. For most practical purposes, it is not necessary to construct a building in order to discover how it performs thermally. Rather, it is possible to apply numerical analyses to the design itself in order to evaluate the likely thermal behaviour of the building. It may be expected that the more thorough the evaluation of the design, then the more fruitful will be the exercise of the construction and evaluation of the prototype.

The evaluation of designs is a field to which particular attention has been given in the application of computers to building design. This is so because the numerical basis of evaluative procedures, such as daylight and thermal analyses, are well suited to computer processing.

5.0 POTENTIAL COMPUTER APPLICATIONS TO THE MICRO PLANNING STAGE

The micro planning stage of the educational buildings planning and design process is concerned with the formulation of short to mid-term strategies for the provision of educational facilities. The demand for educational facilities is at this stage already a known quantity, it being an output from the macro planning stage in the form of enrolment targets. The other side of the equation, that of supply, is determined in the micro planning stage. This is achieved by making a detailed inventory of local resources which must be taken in conjunction with the locally available budget. The subsequent matching of supply and demand produces a number of realistic alternative school building programmes, the selection of one of which for implementation will be determined in relation to physical and cost limits, and to any priorities which may be established.

It will be appreciated from the above that the micro planning stage is similar to the macro planning stage. The similarities between the two stages are as follows:

a) They are both concerned with the formulation of strategies for the provision of educational facilities.

b) They are both concerned with the production of inventories of educational resources.

It follows, therefore, that the micro planning stage offers precisely the same potential for computerization , in terms of the collection, organization and analysis of data, as has already been described in connection with the macro planning stage. The details of this potential need not be repeated here.

It may be noted, however, that much of the data used in the micro planning stage are derived from activities carried out in the macro planning stage. For example, the inventory compiled in the macro planning stage should give a clear indication of the locations of, and the general descriptions of, the educational facilities which already exist in any given locality. To this must be added, at the micro planning stage, detailed information about those facilities, such as, state of repair, nature of surrounding topography, existing infrastructure and so on.

The fact that such data are common to both stages is significant, not only in that it provides scope for computerization, but that the use of computers in this context provides the opportunity of performing the data processing tasks of the micro planning stage with greater ease and expedition. This is because the use of computers for data processing in both stages would facilitate a simple but effective means of distributing the data contained in the centrally compiled inventory to the local educational facilities management units responsible for compiling the detailed school map.

The ways in which this might be achieved are as follows:

a) By recording the data onto one of the storage media such as a disk or a tape and by physically distributing the media onto which the data are recorded to those responsible for carrying out the micro planning stage data processing.

b) By linking the computers being used by those carrying out the local inventory to that used by those who carried out the central inventory and, having made this link, to transfer the data directly from computer to computer. The process by which this may be achieved is known as networking and is effected by making use of the telephone system to transfer the data, in the form of audio signals, from one computer to another. The process itself is relatively cheap and simple. In addition to the normal computing equipment, all that would be required are two devices, known as modems, one at each end of the telephone line. The purpose of a modem is to convert computer data into audio signals, and vice versa.

5.1 Accommodation scheduling

An area of facilities planning which offers considerable scope for computerization is the calculation of the number of spaces required in schools of different enrolments and having different curricula. Although this process of accommodation scheduling is a relatively trivial matter in the mathematical sense, the preparation of a schedule of accommodation is nonetheless a tedious and time-consuming process. Further, a single accommodation schedule is not sufficient as a basis for formulating alternative policies. Rather, it is necessary to prepare a number of schedules each of which answers the same need. All other things being equal, the object of the exercise is to find the schedule with the lowest cost implications.

The purpose of accommodation scheduling is to calculate the number of classrooms required to accommodate a given student population, divided into a number of teaching groups and subject to a particular curriculum. In performing the calculation, the following variables are taken into account:

a) The number of teaching groups, classified by grade.
b) The number of teaching periods per week that the building is in use.
c) The number of periods per week that each group studies each subject.
d) An estimate of the number of periods during which spaces are expected to be used as against the number of periods for which the spaces are available. This is known as the utilization factor and is necessary in view of the practical difficulties of designing timetables based on a 100% utilization of classrooms.
e) Whether the classrooms in question are for general purpose teaching or whether they have specialized uses such as, for example, laboratories.

The relationship between the variables mentioned above is a simple linear one and can thus easily be computerized. In illustration of this is an accommodation scheduling programme written by the author and implemented on a microcomputer. This program consists of the three parts of data input, calculation and output of results. A sample of the data input process is shown in figure 5. It will be noted that the data input is in the form of simple questions posed by the computer, the user providing the answers in the form of data. The computer informs the user that it is waiting for data input by printing a question mark. For the sake of clarity, the user's responses are highlighted in figure 5 by underlining.

At the end of the data input sequence, the computer calculates the number of classrooms required. This is a more or less instantaneous operation and is followed immediately by the output of results. The results sheet relating to the data input described in figure 5 is given in figure 6.

The sequence of input, calculation and output for the example illustrated in figures 5 and 6 was completed in about 5 minutes. Further, once the basic data regarding the student population are already stored in the computer memory, the amendment of some of the data and a repitition of the sequence to obtain an alternative solution would take even less time. Thus, the fundamental advantage of computerizing accommodation scheduling is that it may be performed many times more quickly by computer than by manual means. The result is that it becomes more practical to find a number of different solutions to the same problem, and hence to investigate the problem more thoroughly.

```
INPUT  SUBJECTS  TAUGHT INDOORS  ONLY.      INDICATE
WHETHER TAUGHT IN CLASSROOM (C) OR SPECIAL ROOM (S)

FIRST SUBJECT                              ?RELIGION
C OR S                                     ?C

NEXT SUBJECT                               ?1ST LANGUAGE
C OR S                                     ?C

NEXT SUBJECT                               ?2ND LANGUAGE
C OR S                                     ?C

NEXT SUBJECT                               ?HISTORY
C OR S                                     ?C
.....................................................

INPUT GRADES

1                                          ?6
2                                          ?7
3                                          ?8
4                                          ?9
5                                          ?10
6                                          ?END

INPUT NO OR PERIODS/WEEK/GRADE

SUBJECT                                    RELIGION

GRADE 6                                    ?2
GRADE 7                                    ?2
GRADE 8                                    ?2
GRADE 9                                    ?1
GRADE 10                                   ?1

SUBJECT                                    1ST LANGUAGE

GRADE 6                                    ?6
GRADE 7                                    ?6
GRADE 8                                    ?5
GRADE 9                                    ?5
GRADE 10                                   ?5
.....................................................

INPUT ROOM UTILIZATIONS (0.0 - 1.0)

CLASSROOMS                                 ?0.9
SPECIAL ROOMS                              ?0.75

TIMETABLE PERIODS/WEEK                     ?38
```

Fig. 5. Accommodation scheduling : samples from data input

CURRICULUM

GRADES >	6	7	8	9	10
SUBJECTS	PERIODS TAUGHT				
RELIGION	2	2	2	1	1
1ST LANGUAGE	6	6	5	5	5
2ND LANGUAGE	6	6	5	5	5
HISTORY	4	4	4	3	3
GEOGRAPHY	4	4	4	4	4
PHYSICS	2	2	3	4	4
CHEMISTRY	2	2	3	4	4
BIOLOGY	2	2	3	4	4
MATHEMATICS	6	6	5	4	4
VOCATIONAL	4	4	4	4	4

TOTAL NO OF PERIODS	190
NO OF PERIODS/WEEK	38
CLASSROOM UTILIZATION	0.9
SPECIAL ROOMS UTILIZATION	0.75

ACCOMMODATION REQUIRED

CLASSROOMS	3.65
PHYSICS	0.52
CHEMISTRY	0.52
BIOLOGY	0.52
VOCATIONAL	0.70

Fig. 6. Output from accommodation scheduling programme.

5.2 Cost analysis

In the establishment of an annual building programme, cost will be an important criterion. No final decision can be taken regarding the implementation of a policy unless the resultant cost of that policy is also known. In the absence of detailed building plans, methods other than that of measuring from the plans must be used to estimate costs. One possibility is to assess costs on the basis of various cost indicators. For example, previous school building programmes may have produced data describing the building cost per pupil place and cost per unit area of schools of differing enrolment sizes. Such data provides a suitable basis for determining cost indicators.

Such cost data may be collected and stored using the computerized data processing methods already described. However, the cost data stored in this way are not necessarily in a form suitable for immediate use as cost indicators. They may, for example, require weighting to take account of the building costs in different geographical locations, or of the effects of inflation. In the first of these examples, statistical analysis may be appropriate and, as has already been seen, may readily be carried out on a computer. The effects of inflation may be expressed in relatively simple mathematical terms. Since computers are well suited to the evaluation of mathematical relationships, the inflation problem may also easily be computerized.

The computerization of the cost analysis problem has interesting consequences. These result from the direct association between accommodation scheduling and costing. Having established an accommodation schedule, the area of the building corresponding to that schedule can readily be calculated and, by application of suitable cost data, the likely cost of the building may be calculated. Thus, the use of computers for the processing of cost data may be taken one step further if the accommodation scheduling problem is also computerized. In view of the direct relationship between the two processes, both may be implemented on a computer as a single process. Such is the basis of the ECOLE 1 program prepared by ABACUS, Strathclyde.

A major virtue of integrating the computational processes of accommodation scheduling and cost analysis is that it enables rapid computation. Thus, the most fruitful use for such an integrated program is in connection with problems whose solution require repeated applications of calculations. An example of this is the problem of determining an economic enrolment size for a catchment area in which the options are either to build a few large schools or a large number of smaller schools with lower enrolments. This requires repeated calculation on a trial-and-error basis, to which computer-based methods are well suited.

6.0 POTENTIAL COMPUTER APPLICATIONS TO THE IMPLEMENTATION STAGE

The implementation stage of the educational buildings planning and design process is the production phase of the process in which sites are selected, architects briefed, designs prepared and construction carried out. There are already a number of computer applications to the architectural, engineering and constructional fields at large. It follows, therefore, that there is considerable scope for the application of computers to the implementation stage. Two areas in particular offer scope for computer applications. These are the pre-contract and the construction management phases of the implementation stage.

6.1 Pre-contract applications

There are currently a large number of successful computer applications to the process of building design. It must be made clear, however, that such applications are not concerned with the automation of the entire design process to the extent that the building designer becomes obsolete. Neither architecture nor engineering are rigid sciences and value judgements are fundamental to the process of design in both disciplines. Whilst there has been a certain amount of research into the problem of computer generated building design, such work tends to remain as stuff of the future.

Existing computer applications to the pre-contract phase may broadly be classified as follows:

a) Development of design solutions.

b) Evaluation of design solutions.

c) Preparation of production drawings.

The application of computers to these areas of the building design process is known as computer-aided design (CAD).

6.2 Development of design solutions

A general and somewhat logical axiom of building design is that the relationships between the spaces in a building should reflect the pattern of functional relationships between the activities accommodated in those spaces. The possibility of using computers to interpret the functional relationships between activities and of using the information thus gained to automatically generate building layouts formed the basis of much early CAD work although, as will be discussed presently, such CAD applications are now much less common.

An example of such an application to the field of educational building design is the SPACES suite of programs produced by the Architecture and Building Aids Computer Unit, Strathclyde. The SPACES suite of programs is divided into three parts, SPACES 1, SPACES 2 and SPACES 3. Of interest here are SPACES 1 and SPACES 2. SPACES 1 is a program which, given a curriculum and space standards per person, performs an analysis which determines the areas required to support that curriculum and the utilization factors of those spaces.

SPACES 2 is that part of the SPACES suite designed to generate built-form layouts. This takes as its input a schedule of accommodation, the functional relationships between activities in the form of an association matrix and any relevant planning constraints. The program translates these data into a bubble diagram which may be modified by the designer if necessary. The bubbles are then transformed into squares by the program which can be manipulated by the designer to form a building layout.

It will be noted from the above description that in fact, an automatic generation of a building layout does not take place. Rather, considerable input is required from the designer in defining the basic spatial concepts of the layout. This characteristic is typical of CAD programs intended for the preliminary stages of the design process. Because such programs assist, rather than completely automate, the functions of the designer, they are known as design aid programs. Although the development of design aid programs formed much of the thrust of early CAD work, interest in them has tended to diminish as they have not, as a rule, been found to be cost-effective. Further, they often took account of too few of the factors which influence the design of a building. In the case of layout generation, for example, the major criterion was generally taken to be functional relationships. In reality, other factors such as structure and services are equally important. It is in acknowledgement of this that SPACES 2 makes provision for the designer to intercede during the execution of the program.

A rather more useful computer application at this stage of the design process is in structural design. Computers are commonly used in the analysis of structural elements such as beams, columns, frames, footings, retaining walls and so on. Indeed, some types of analysis, such as the dynamic analysis of a whole structure, are so complex that the use of means other than a computer for their execution are not realistic.

As in the case of the functional analysis programs such as SPACES, computer programs for structural analysis can generally be classified as design aids rather than solution generators. This is in view of the types of input data required from the designer. In addition to data describing the problem constraints, such as span and loading, data describing the designer's assumptions are also required. In the case of a beam, for example, the designer might be required to indicate the assumed width of the beam. Based on these data, the computer program would test the assumptions by calculating such characteristics as bending moments, shear stress and deflection whilst more sophisticated programs may also calculate areas of steel required and produce a limited amount of structural drawings. The time taken to carry out this process by manual methods can be very long. Thus, one of the major advantages of the use of computers for structural analysis is in the amount of time they are able to save.

6.3 Evaluation of design solutions

The evaluation of design solutions has generally represented a relatively fruitful area for computer applications. Some of the types of application, and their associated problems, have already been discussed elsewhere (4.4) and require no further elaboration. Not previously mentioned is an application related to the evaluation of sites and which is thus of particular relevance to the implementation stage. This application involves the use of computers to calculate the amount of cutting and filling required in preparing a site for the construction of a particular building. The value of assessing the amount of cut and fill necessary lies in being able to determine the cost of the work involved. Despite the relevance of this application, however, it may be noted that that the performance of cut and fill calculations by manual means is not a very difficult task so that it is open to question as to whether the application is ultimately a very useful one.

6.4 Preparation of production documents

One of the most common and cost effective computer applications to the building design process at present is in the preparation of production documents. This applies predominantly to the preparation of drawings although computers are also used in the production of schedules and bills of quantities, usually as a by-product of their use in the production of drawings.

Computer aided drafting programs are generally capable of performing the same functions as a draftsman would perform manually. However, the true benefits of most modern computer aided drafting systems are derived not from their ability to reproduce the functions of the draftsman but from their additional capabilities which both speed up and enhance drafting procedures. It is important to note, however, that some of the older computer aided drafting systems, still commercially available, are slower than manual drafting methods.

One of the major advantages of computer aided drafting over manual methods is the speed at which it is possible to compose drawings. This speed is possible as a result of a number of factors not least amongst which is the ability to reproduce standard building elements very simply and quickly. Most computer aided drafting systems permit the definition of standard components at a number of different levels. For example, a standard door type, recurring many times in a building plan would, in the manual process of drafting, have to be drawn out at every occurrence. In computer aided drafting, it need only be drawn once. Upon every subsequent occurrence of the door, a copy of the door, defined as a component and stored in memory, is positioned in the appropriate place in the drawing. Typically, this would be achieved with one or two simple instructions to the computer. This facility becomes especially beneficial at the higher levels of component definition when, for example, a whole room or an entire storey is defined as a component. An example of this, in the school building context, is that of the classroom which, for any given school building, will tend to be of a standard size.

Computer aided drafting techniques also embody facilities to speed up the production of a whole set of construction drawings. A single drawing in a set of construction drawings may contain information common to the other drawings. For example, all the plans may contain a planning grid whilst a services plan may depict much of the building works. In preparing the construction set by manual means each drawing is individually drafted. Thus much of the drafting time is spent redrafting elements already drawn previously on another drawing. This repetitive element can be avoided in computer aided drafting by

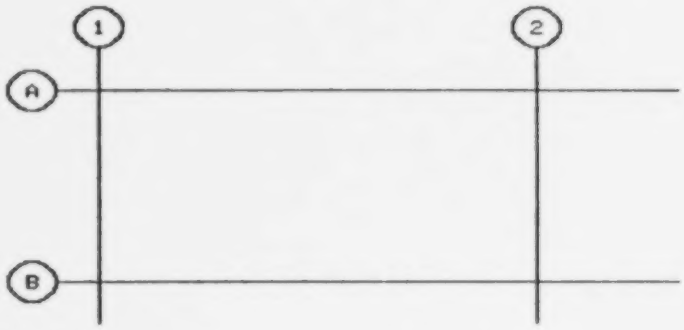
use of the technique of overlaying. The principle of overlaying is that each category of information, such as planning grids, services, structure and so on, is stored separately. These different types of information may then be combined in different arrangements to produce different types of drawing such as, for example, a services drawing or a structural drawing. These principles are illustrated in figures 7 and 8.

Figure 7 shows 3 different types of information, each of which might be stored separately. Figure 8 shows how different combinations of this information produce different types of drawing.

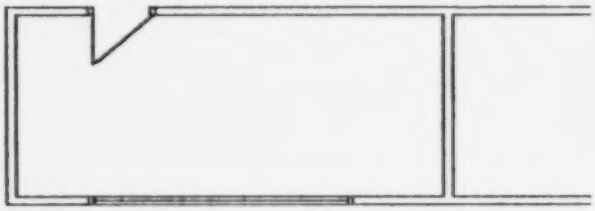
Other aspects of computer aided drafting are also aimed at speeding up the drafting process. For example, a drawing may quickly and simply be reproduced at any scale, thus avoiding the need to redraw an entire drawing in the event that it is required at a different scale from that originally drawn. Computer aided drafting enables text to be placed on drawings very quickly as it involves nothing more than typing the information at the keyboard and positioning the resulting text in the appropriate position on the drawing. In addition, many computer aided drafting systems have facilities for the automatic dimensioning of drawings.

A number of systems, but not all, also facilitate the automatic production of textual information associated with drawings such as schedules or bills of quantities. For example, door schedules or, in the school building context, furniture schedules, might be automatically generated by the system. One major advantage of such automatic generation is that if, at any stage, the drawing is amended, then so too is the associated schedule.

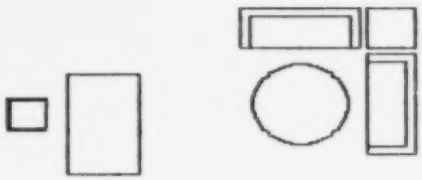
Computer aided drafting systems are most ideally suited to designs which are highly repetitive in nature and have therefore often been used in connection with industrialized building systems. However, repetitiveness of the order evident in industrialized building systems is not a prerequisite for the economic use of computer aided drafting systems. The fact is that even apparently unique buildings are likely to contain a number of repetitive elements such as, for example, doors, windows, sanitary fittings and so on. In a large and complex building, the consideration of repetitiveness may become less important since the advantages which may be derived as a result of the use of overlaying techniques may in themselves be sufficient to speed up the drafting process significantly.



PLANNING GRID OVERLAY

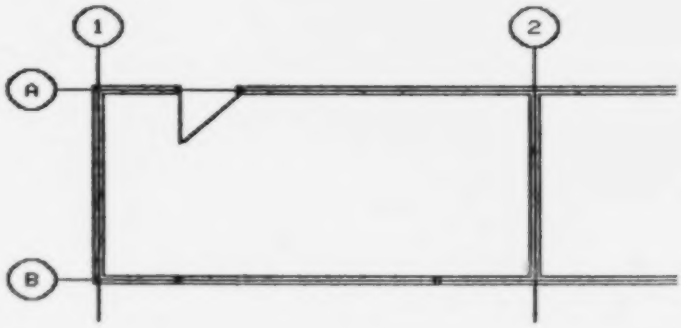


CONSTRUCTION OVERLAY

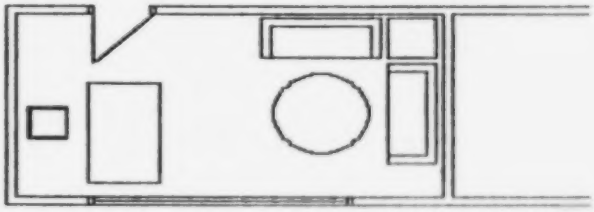


FURNITURE OVERLAY

Fig. 7. Examples of overlays



PLANNING AND CONSTRUCTION OVERLAYS



CONSTRUCTION AND FURNITURE OVERLAYS

Fig. 8. The use of overlays

The nature of school building plans is such that a certain level of repetitiveness may be expected and computer aided drafting may thus be of interest to school building designers. A situation in which a good measure of repetitiveness may be evident is where school building designers are responsible for the preparation of production documents for more than one school, such as for example in the context of a regional or national school building programme. Computer aided drafting methods would be ideally suited to such a situation. It is claimed that the use of computer aided drafting may increase productivity manifold. This characteristic raises the interesting possibility that where school building programmes are related to annual budgets, the consequent need to complete the design and to place construction contracts within the budget period may be more readily satisfied through the use of computer aided drafting techniques.

6.5 Construction management applications

The final phase of the implementation stage is concerned with the construction of educational buildings. The major task for planners and designers at this stage is that of the control and management of construction. Computers have successfully been applied to some aspects of the management of construction projects, particularly in relation to the programming of construction works and also to the monitoring of the progress of the works.

Traditionally, the programming of construction works has been carried out by manual methods. Such programming may be represented in many different ways. At the simplest level is the bar chart which indicates, against a time scale, the period during which each activity in the construction process is scheduled to take place. At a higher level is a more informative method of construction programming, that of the network. Unlike the bar chart this shows not only the periods scheduled for the execution of each activity but also describes the particular sequence in which activities must be performed.

A yet more refined version of the network also shows the earliest and latest possible commencement dates of each activity. This additional information makes it possible to identify the critical activities in any construction sequence, that is, those activities which must be completed on time in order to avoid an overall delay to the project. This method of construction programming is known as the critical path method.

The value of such programming methods is that they serve both as planning aids and as yardsticks for monitoring the progress of projects. As planning aids, they make it possible to estimate the amount of resources, be they financial, material or human, which will be required at each stage of the project. As monitoring instruments, they make it possible to assess whether projects are progressing satisfactorily or whether additional resources will be required to make up for time lost at some previous stage in the construction sequence.

In the case of small projects, it is possible to apply the critical path method of project control by manual means. For large and complex projects, however, the critical path method may only realistically be applied on a computerized basis. The use of computers for applying construction programming methods is particularly beneficial as an aid to the monitoring of progress. Where circumstances are such that progress on the building site deviates, as is so often the case, from that projected on the programme, it is essential to update the programme accordingly. Further, any measures aimed at speeding up progress should be incorporated into the revised programme at this stage. Ideally, programme updating should be carried out on a regular basis. If this is not done it may become increasingly difficult to make an accurate assessment of the state of subsequent progress. Where manual methods are used, there is often a tendency to avoid programme updating because the task is both difficult and very time-consuming. The value of computer implementations of programming methods is that they make the updating process much simpler and faster thus enabling updating to be carried out at the proper intervals.

7.0 COMPUTER APPLICATIONS: CONSIDERATIONS FOR IMPLEMENTATION

The process of implementing a computer application is not an easy one. The difficulties may be minimized, however, by approaching the process in as systematic a way as possible and by making a thorough assessment of the feasibility of implementing the application. Such assessment should be made chiefly in terms of the four considerations of the user's requirements, software, hardware and personnel.

7.1 User requirements

The first step in assessing the feasibility of a computer application is the detailed analysis of what is required. This process should include the following:

a) An examination of the activities which take place within the user organization. From this, it should be possible to identify precisely which activities are to be computerized.

b) A definition of the manner in which the user performs the activities likely to be computerized. This is to enable the selection of a computer system which suits the organization's working methods. Different computer systems are geared to different methods of working and care should be taken not to select a system which imposes an unacceptable method of working on the user.

c) An analysis of likely future changes within the organization. This will enable the determination of a long term computer implementation strategy based on the likelihood of future changes in the nature or size of computer applications. Clearly, software which is capable of accommodating such change should be selected.

d) A statement of the budget available for both initial and in-use costs. Initial costs are the capital costs of hardware and software. In-use costs are those of staff training and hardware and software maintenance.

7.2 Software considerations

Software may be obtained in a number of different ways. For many applications, it is possible to purchase ready-made software. In searching for suitable software there are a number of avenues which may be explored. One useful source of information is in directories of software (1). However, the computing field is subject to rapid change and such directories become outdated very quickly. The information contained in directories should therefore be supplemented by information from other sources such as, for example, current periodicals and recent conference papers. Other sources are similar organizations which are already making use of computers, and computer manufacturers. Where available, use may also be made of consultants.

There are two ways of buying ready-made software. The first is through the purchase of a 'turn-key' computer system, a system which is sold as a package including both hardware and software. Turn-key packages are most commonly found in connection with the more expensive and specialized applications such as computer aided drafting. The second method is to buy 'off-the-peg' software. This consists simply of one or more programs ready for immediate use. It may be that ready-made software can be found which is approximately, but not perfectly, suited to the user's needs. In this case, it may be possible to have the software modified to meet those needs although it may be noted that the costs and likely degree of success of customizing software are difficult to estimate.

Once the availability of software has been established, its suitablity should be assessed. Preferably, a shortlist of potentially suitable software should be compiled thus enabling assessment on a comparative basis. The software should be assessed in terms of whether it will perform the task the user wishes to computerize and of whether it will facilitate acceptable methods of working. An initial assessment of these characteristics may be made with reference to the software documentation although, ultimately, there is no substitute for making trial use of the software. A trial run will be most fruitful if it is made with reference to a problem drawn from the user organization. The adoption of this problem as a standard for comparative testing is particularly useful in identifying the most suitable of the shortlisted software.

1. Hutton, G. and Rostron, M. Computer Programs for the Building Industry. London, Architectural Press, 1979.

A major consideration in the purchase of software is the lack of hardware standardization. Thus, software written for implementation on one type of computer will not necessarily run on a machine produced by another manufacturer. Indeed, even different machines produced by the same manufacturer are often incompatible. Software which is compatible with more than one type of computer is said to be transportable. Although not always available, transportable software is to be preferred. Computer hardware tends to become obsolete much more rapidly than software and it is thus possible that, at least once in the course of its life, the software may have to be installed on new hardware. It is often difficult to establish whether a particular program is transportable. As a general rule, a transportable computer program will be written in one of the high-level languages although, for technical reasons, it is inefficient to write a program of substantial size entirely in a high level language and it would be usual to expect a good program to contain a certain amount of machine code.

It should be less difficult to determine the transportability of established and well-proven ready-made software since the operating characteristics of such software will probably be well known. Indeed, it is in view of the relative ease of determining the general performance of proven software that purchasers of ready-made software are advised to give it greater preference. An additional consideration, in this respect, is that proven software should also contain less of the errors to which new software is occasionally prone.

As an alternative to buying software the writing of new software may be considered. This may be achieved on the basis of a commission to an external agency or programmer or by using the expertise available within the user organization to write the software 'in-house'. In both cases, however, it must be noted that good software takes a long time to write so that, even for small applications, estimates of the software development period should be as generous as possible.

This raises the question of cost. The cost of software is almost directly related to the number of man-hours devoted to its development. The result of this, in many countries, is that off-the-peg software is generally cheaper than custom-written software since its development costs are spread over a greater number of users. However, this may not necessarily follow in the case of some Asian countries where salary structures differ greatly from those in countries where the use of computers is well-established.

7.3 Hardware considerations

The choice of hardware for a particular computer application should ideally be influenced by the nature of the application and by the characteristics of the application software. For example, whilst electronic data processing and computer aided drafting may be able to make use of the same central processing unit they will almost certainly require different peripherals. Similarly, the application software may, because of the transportability problem, impose restrictions on the range of suitable hardware. In effect, therefore, the selection of hardware and software are often made together. This is particularly true of the more specialized applications such as computer aided drafting which are very often the subjects of turn-key systems. Indeed, it is in view of the difficulties of selecting compatible software and hardware that turn-key systems are greatly to be recommended.

Even with turn-key systems, however, it is still important to assess the quality of the hardware. Similar considerations apply as in the choice of software. Thus, it is preferable to consider widely-used hardware produced by a reputable manufacturer. To guard against the problems of obsolescence, it is wise to consider equipment produced by manufacturers who have a reputation for producing equipment compatible with their previous models. The prospective purchaser should visit as many similar hardware installations as possible in order to assess performance characteristics at first hand.

In assessing hardware, the quality and suitability of the peripherals should also be taken into account. The range of peripherals is large and it is unusual for a single manufacturer to produce the entire range. It is nonetheless preferable that as much of the hardware as possible in any installation be produced by a single manufacturer. This will help ensure technical compatability between the various items of equipment and will also simplify the maintenance process.

The availablity of maintenance facilities is a further key factor in the choice of hardware. Minicomputers and mainframes normally require routine servicing. Further, occasional break downs will inevitably occur in all types of computers. The effects of this can be severe and a computerized operation may often be halted by equipment failure. It is therefore of the utmost importance that a good maintenance service and a plentiful supply of spare parts be available. To this end, it is usual to sign a maintenance contract with the equipment supplier. If the supplier is not able to provide this service then, no matter how good the equipment, it is undoubtedly better to take one's business elsewhere.

7.4 Personnel considerations

The computerization of any task implies the need for some computing expertise. The level of expertise required varies according to the type of application and to the type of computer system being used. A guide to expertise requirements may be given in relation to the following categories of specialist computing personnel:

a) Systems analyst - one who analyzes a problem into its constituent parts and hence describes the problem in a systematic way. Although systems analysis is not peculiar to computing, in the computing sense, the description produced by a systems analyst may be taken as the brief for the writing of a computer program.

b) Computer programmer - one who writes computer programs. That is, one who develops programming briefs into software.

c) Computer/system operator - one who is familiar with the mode of operation of a computer installation and who operates the computer system on behalf of the user or users.

The above definitions are, however, based on somewhat theoretical circumstances and there are many instances, particularly in the case of smaller installations, where some of the functions mentioned above are taken over by non-specialist personnel. For example, in the case of many minicomputer and microcomputer installations, it is very often the user who assumes the role of the computer operator. One reason for this is that there has been great emphasis, in recent years, on making computer systems 'user friendly'. That is, the instructions and procedures which accompany the system have tended to become more straightforward and hence more easily understood by non-specialist personnel. An additional consideration is that the definitions given above are not rigid and, in general terms, both a systems analyst and a computer programmer should be able to perform any of the three functions. The question of whether staff functions may be interchanged in this way will depend on the context. For example, in a computer installation operating on a commercial basis, the question will probably be an economic one, whereas in a research-based installation, other considerations may apply.

It may also be noted that computing has become very much a part of the syllabus in universities and even in secondary schools. Most engineering graduates and some architectural graduates, for example, have some contact with computers in the course of their training and most of these should be capable of an elementary level of computer programming. The result of this is that small to medium sized installations and applications, and particularly those which are based on turn-key systems, are often staffed by personnel who may be described as semi-skilled in computing.

These are, however, special cases, and it should not be assumed that specialist computer personnel are an unnecessary luxury. In terms of the applications envisaged in connection with the educational buildings planning and design process such personnel would certainly be required. Precise staffing levels will obviously depend on circumstances. However, an approximate indication of staffing requirements may be given, as follows:

a) In general, main frame installations supporting large scale applications would require varying numbers of each of the three types of specialist personnel.

b) Applications involving substantial amounts of software development will require computer programmers. It is preferable that expertise in systems analysis be available.

c) Turn-key applications do not, in theory, require specialist personnel although it is wise to appoint a manager to run the system. Such a manager should be capable of acting as a quasi-systems analyst by co-ordinating the needs of the user organization with any specialist inputs required such as, for example, arranging for software and hardware maintenance.

A final personnel consideration is that of ensuring good communications between specialist computing personnel and the personnel from the user organization. In the absence of such liaison, problems may arise. In the context of the educational buildings planning and design process, for example, the programmer may not fully understand the nature of the educational buildings problem whilst the architect or engineer, on the other hand, may not appreciate the limitations of the computer system. The effect of such a situation may be to diminish the eventual success of the application. A possible means of overcoming this expertise barrier is to consider the use, in a systems analyst's role, of the type of computer-conscious architectural and engineering graduates mentioned earlier. Such personnel should, for example, adequately be able to fulfil the systems analysis and managerial roles mentioned in b) and c) above.

8.0 THE EDUCATIONAL BUILDINGS PLANNING AND DESIGN PROCESS: THE IMPLEMENTATION OF COMPUTER APPLICATIONS

A number of potential computer applications to the educational buildings planning and design process were identified in Sections 3.0 to 6.0. In this section, the considerations discussed in Section 7.0 are applied to each of those potential applications in turn. For the purposes of easy reference, the hardware and software requirements of each application are summarised in Figure 9, overleaf. This is followed by more detailed information in the form of data sheets, one for each application. These are intended as basic reference material for consultation and expansion by those contemplating implementation of the applications. The reader who has no immediate interest in the implementation of the applications is advised to proceed directly to Section 9.0.

In compiling the data sheets, consideration has been given to the type of hardware which might be used in connection with each application. It should be noted that, whilst many of the applications could in fact be implemented on either mainframes, minicomputers or microcomputers, the data sheets refer only to the hardware which seems most relevant in the context of the educational buildings planning and design process. Similarly, where mention is made of peripherals, references are only to essential peripherals. This does not mean that other peripherals not mentioned are not required or, indeed, that where no mention of peripherals is made at all, none are required.

A summary of terms and abbreviations used in the sheets is given at the end of the section.

STAGE	SOFTWARE		HARDWARE		
APPLICATION	OFF-THE-PEG	PURPOSE WRITTEN	MAIN	MINI	MICRO
MACRO PLANNING					
1. Facilities inventories : data processing and analyis.	A	L	S		S
RESEARCH AND DEVELOPMENT					
1. Establishment of norms and criteria : statistical analysis.	A				S
2. Determination of cost limits : cost limit model.		R		S	S
3. Preparation of design guidelines : simulation modelling.		R		S	S
4. Evaluation of prototype designs.	A	C		S	S
MICRO PLANNING					
1. Facilities inventories : data processing and analysis.	A	L	S		S
2. Preparation of accommodation schedules.	A	C			S
3. Cost analysis.	A	C	S		S
IMPLEMENTATION					
1. Development of design solutions : structural analysis.	A	C		S	S
2. Evaluation of design solutions.	A	C		S	S
3. Preparation of production documents.	A			S	S
4. Construction management : project programming and control.	A	C		S	S

A = Available, L = Limited application, R = Purpose-written software required,
C = Purpose-written software to be considered, S = Suggested.

Fig. 9. Summmary of software and hardware requirements

STAGE : Macro Planning

APPLICATION : Facilities inventories: data processing and analysis

SOFTWARE : Off-the-peg e.d.p. software is available. Purpose-writing of data processing software is not recommended except for very small applications. Purpose-written database application software will probably be required.

HARDWARE : Main or micro suggested.
Peripherals - external storage facilities with high storage capacity will be required.

EXPERTISE : Computer programmer required for writing database application programs.

COMMENTS : In many countries in the region, the government may possess mainframe facilities with e.d.p. software. It is suggested that, where available, the surplus capacity of such installations might be used for the e.d.p. needs of the educational buildings planning and design process.

As an alternative, microcomputer based e.d.p. applications seem most promising. The use of off-the-peg database processing software with purpose-written applications software is suggested.

STAGE : Research and development

APPLICATION : Establishment of norms & criteria: statistical analysis

SOFTWARE : Statistics software is available off-the-peg. Purpose-written software may also be considered.

HARDWARE : Micro suggested.
Peripherals - good external storage device required.

EXPERTISE : A knowledge of statistics is sufficient for off-the-peg programs. Programming and statistical knowledge will be required for purpose-written programs.

COMMENTS : Microcomputer-based programs should be adequate.

SHEET 3

STAGE : Research and development

APPLICATION : Determination of cost limits: cost limit model

SOFTWARE : Off-the-peg software is available but is probably not useful and purpose-written software will be required.

HARDWARE : Mini or micro suggested.
Peripherals - good external storage device required.

EXPERTISE : Systems analyst with knowledge of operations research techniques and computer programmer required.

COMMENTS : There are two stages to implementation. The first is a theoretical one to develop the cost limit model. The second is the development of the software. It is uncertain as to whether the cost limit model will be feasible. Further, it is not clear what type of computer will be required for implementation. A minicomputer will certainly be adequate but the possibility of using a micro should be investigated. If the implementation of this application is envisaged, it is suggested that a pilot study be carried out to determine the feasibility of the cost limit model and to examine what type of hardware will be required.

STAGE : Research and development

APPLICATION : Preparation of design guidelines: simulation modelling

SOFTWARE : Off-the-peg software is not available and purpose-written software will be required.

HARDWARE : Mini or micro suggested.

EXPERTISE : Systems analyst with knowledge of simulation modelling techniques and computer programmer.

COMMENTS : There are two stages to implementation. The first is the theoretical one to design the simulation model. The second is the development of the software. A minicomputer will be adequate and possibly even a microcomputer. If implementation of this application is being considered, it is suggested that a pilot study be carried out to determine the type of computer required.

SHEET 5

STAGE : Research and Development

APPLICATION : Evaluation of prototype designs

SOFTWARE : Some off-the-peg software is available. Purpose-written software may also be considered.

HARDWARE : Mini or micro suggested.

EXPERTISE : Programming knowledge is required if purpose written software is to be used.

COMMENTS : Some evaluation programs are included in computer aided drafting systems. A number of individual evaluation programs are also available. However, with individual programs, the time taken to describe the building may often be longer than that taken to perform the evaluation by manual means. In answer to this problem are a number of evaluation packages which are able to perform a range of evaluations. The advantage of these is that it is only necessary to describe the building once and to use that description as a basis for a number of different evaluations, thus saving a considerable amount of time.

SHEET 6

STAGE : Micro planning

APPLICATION : Facilities inventories; data processing and analysis.

SOFTWARE : See macro planning stage, sheet 1.

HARDWARE : See macro planning stage, sheet 1. If networking is being considered, hardware with network facilities will be required. In addition, network facilities at each end of the communications link should be compatible. This is important as there is not yet standardization in networking technology.

EXPERTISE : See macro planning stage, sheet 1.

COMMENTS : See macro planning stage, sheet 1.

STAGE : Micro planning

APPLICATION : Preparation of accommodation schedules.

SOFTWARE : Some off-the-peg software is available. Purpose-written software may also be considered.

HARDWARE : Micro suggested.

EXPERTISE : Programming knowledge required for purpose-written software.

COMMENTS : Microcomputers should be adequate for this application. The use of portable microcomputers may also be considered for conducting accommodation scheduling exercises in the field. Battery powered portable microcomputers are available. Some of these have small screens, printers and tape storage devices inbuilt. Because of the restricted size of some of these, input and output procedures may be somewhat cumbersome. However, there are some models which are suitable and, indeed, the program described in Section 5.0 has successfully been implemented by the author on such a machine. It may also be noted that portable computers are likely to become increasingly more sophisticated in the future.

STAGE : Micro planning

APPLICATION : Cost analysis

SOFTWARE : Some off-the-peg software is available. However, purpose-written programs should also be considered.

HARDWARE : Main or micro suggested. Networking facilities may be required if the data used in the cost analysis has been processed on another computer.

EXPERTISE : Programming knowledge required for purpose-written software.

COMMENTS : A microcomputer should be adequate for this application. However, in the event that the e.d.p. of the input data required for cost analysis is carried out on existing mainframe facilities a microcomputer may still be used for the cost analysis portion of the application provided that networking facilities are available.

STAGE : Implementation

APPLICATION : Development of design solutions: structural analysis.

SOFTWARE : Off-the-peg software is available. Some of this is capable of dealing with very complex problems and may not be required for most of the types of problems encountered in the educational buildings planning and design process. Purpose-written software may be considered.

HARDWARE : Mini or micro suggested.

EXPERTISE : Systems analysis and programming knowledge required for purpose-written programs.

COMMENTS : For most of the problems encountered in the educational buildings planning and design process, a microcomputer should be adequate. It should be possible to write programs for most typical structural analyses. The writing of programs for the analysis of simple beams, columns, etc. should not present too many problems.

STAGE : Implementation

APPLICATION : Evaluation of design solutions.

SOFTWARE : See research and development stage, sheet 5.

HARDWARE : " " " " " "

EXPERTISE : " " " " " "

COMMENTS : " " " " " "

STAGE : Implementation

APPLICATION : Preparation of production documents.

SOFTWARE : Off-the-peg software is available, mostly turn-key. Purpose-writing of software not recommended.

HARDWARE : Mini or micro suggested.
Peripherals - plotter, graphics v.d.u., external storage device with high storage capacity.

EXPERTISE : No special knowledge required beyond training provided by system supplier.

COMMENTS : Until recently, CAD software has only been available in the form of minicomputer-based implementations. Such implementations would generally be essential in connection with large and complex projects being carried out in a commercial context. There is, however, now a large number of microcomputer-based CAD software available. Such software should be adequate for many of the production documentation problems associated with the educational buildings planning and design process. For minicomputer implementations, computer aided drafting hardware would usually be used solely for the purpose of drafting. Little surplus capacity would be available for other tasks. Conversely, minicomputer-based computer aided drafting systems would not usually be implemented by using the surplus capacity on an existing hardware installation.

STAGE : Implementation

APPLICATION : Construction management: project programming and control.

SOFTWARE : Off-the-peg software is available. Purpose-written software may also be considered.

HARDWARE : Mini or micro suggested.

EXPERTISE : Knowledge of construction management techniques preferable in connection with off-the-peg software. The development of purpose-written software would, in addition, require programming knowledge.

COMMENTS : The more complex applications would need to be implemented on minicomputers. However, microcomputer-based applications should be able to cope with a fairly comprehensive range of problems of average complexity.

8.1 Terms and abbreviations

The following are the terms and abbreviations used in this section.

Main	Mainframe computer
Mini	Minicomputer
Micro	Microcomputer
E.d.p.	Electronic data processing
Purpose-written	Commissioned or in-house software

9.0 PROSPECTS

There are many tasks and procedures which could be performed by computer. For a good number of these, however, there would be little financial justification for doing so. Further, there is not always the guarantee that having computerized the task, the result will be more beneficial than the existing manual means.

So it is with the educational buildings planning and design process. It is not inconceivable that ultimately a large part of the process could be computerized. Given the current state of knowledge and technology, however, the potential for the application of computers to the process is much more limited, a potential which is reduced still further by the consideration of what is practical as opposed to what is possible.

This consideration has been embodied in the foregoing descriptions of the potential for the application of computers to the educational buildings planning and design process. In compiling these descriptions the underlying theme has been one of caution, emphasis being placed on the most practical ideas.

The scope of the discussion has further been constrained by the size and diversity of the range of hardware and software available, in view of which, no attempt has been made to give exhaustive lists of suitable hardware and software. Neither, indeed, have detailed descriptions been given of how a particular computer application would be implemented. Rather, the chief intention has been to alert to the possibilities which exist. Detailed studies may more appropriately be made once the specific requirements of those intending to apply computers in their work are known.

Of the possibilities which have been identified, two areas seem particularly relevant. The first is electronic data processing and the second, microcomputer applications. Two relatively straightforward means of implementing electronic data processing have been identified. First, where possible, use may be made of existing main frame facilities. This option is of interest as there are no capital costs involved. The second alternative is to implement the electronic data processing on a microcomputer, the capital costs of which are low.

Electronic data processing is but one of the potential microcomputer applications identified. For the newcomer to computing, microcomputers provide an ideal means of gaining practical experience of computing, for which, according to an old computing maxim, there is no substitute. Microcomputers and their associated software are relatively cheap and the investment risks are low. Hence, the software and hardware assessment process may be less rigorous and bewildering than in the case of the larger machines. From experience gained on a microcomputer, a first time user will be better equipped to decide on a longer term computing strategy involving, perhaps, a shift in the nature of application or possibly the purchase of a larger machine.

In view of likely future developments, however, it is by no means certain that large machines will be necessary for the implementation of most of the applications discussed here. The rate of development in computing is rapid. Increasingly, future developments are likely particularly to affect the state of the microcomputer art. Important developments are likely to concern both software and hardware. The greater miniaturization of circuitry should lead to cheaper microcomputers that will perform better and will be more powerful. Improved and more standardized methods of communication are likely to lead to an increased level of networking. Methods of input will probably become simpler. New and more reliable storage media are likely to make higher storage capacities possible whilst software will almost certainly become more portable and much easier to use.

Whilst it is dangerous to make technological predictions, the types of development mentioned above are already beginning to emerge, in view of which, the rationale for becoming a microcomputer user is far more compelling than that simply of the need to gain experience in computing. The software and hardware developments now in the offing are likely to result in an extremely favourable productivity to cost ratio for microcomputers. A trivial but apt analogy is the digital wristwatch which, in the space of less than a decade, has become possibly the cheapest form of timepiece. At the same time, the control circuitry on which the digital wristwatch depends for its operation has enabled an increase in the number of functions of the apparatus so that, for example, many digital wristwatches now function also as calenders, calculators and even as storage devices for small amounts of data. Microcomputers are likely to follow the same trend towards lower costs and higher power and, indeed, it would not be too bold to suggest that the time is now not too far removed that the productivity to cost ratio of computers, and particularly of microcomputers, will become so beneficial as to be impossible to ignore.

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